Assessment of Gas and Electricity Savings for Homes Treated under Wisconsin's Home Energy Plus Low-Income Weatherization Program

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1.0 Introduction

Since fiscal year 2009 an annual evaluation has been conducted of delivered energy savings for gas-heated homes that have been treated by the Wisconsin Home Energy Plus Low-Income Weatherization Program. To determine energy savings, monthly gas and electric billing records for the homes treated that year are collected from Wisconsin's five investor-owned utilities. Billing data from pre- and post-weatherization periods are weather-normalized and the difference between them is used to estimate therm and KWH savings for each treated home. For each fiscal year analyzed, pre-weatherization billing data of future participants is used to correct for non-program effects and for errors in weather adjustment modeling. Savings estimates are then coupled with data taken from the program's tracking database to evaluate savings by housing type, local agency and installed weatherization measures (see Appendix B for a detailed description of the analysis).

Multiple forces, both internal and external, have had an impact on the program throughout the five years analyzed. These forces include both the advent and sunset of the American Reinvestment and Recovery Act (ARRA) and a significant change (decrease) in the program's reference gas prices, which are important inputs for pre-weatherization cost-effectiveness testing. In addition the program continuously adjusts policies in an effort to increase cost-effectiveness and enhance program delivery. Some of the policy changes over the past five years include moving to a 100 percent electronic audit (versus a measures list) and implementing additional oversight on non-energy conservation measure spending. Thus, evaluating the year-to-year variation in savings is instructive within the context of these external and internal forces.

Figure 1 shows the number of housing units weatherized between FY09 and FY13. As seen in Figure 1 there was a large increase in the number of homes treated by the program during the ARRA period (principally during FY10 and FY11). Gas-heated homes have traditionally comprised approximately three-quarters of the housing units treated in 1-4 unit structures. In all, the analysis dataset of pre- and post-weatherization billing data for the years depicted in Figure 1 represents approximately 16,000 homes, or about half of the gas-heated homes weatherized during the same time period. Figure 2 shows the number of gas heated housing units weatherized between FY09 and FY13. Among gas-heated homes, single-family homes have typically accounted for between 50 and 60 percent of treated housing units, except during FY11 and FY12, which saw a big increase in large multi-family buildings due to a special ARRA-period initiative called the ARRA Multi-family Project, or AMP.

Figure 1. Housing units in 1-4 unit structures treated between FY09 and FY13.

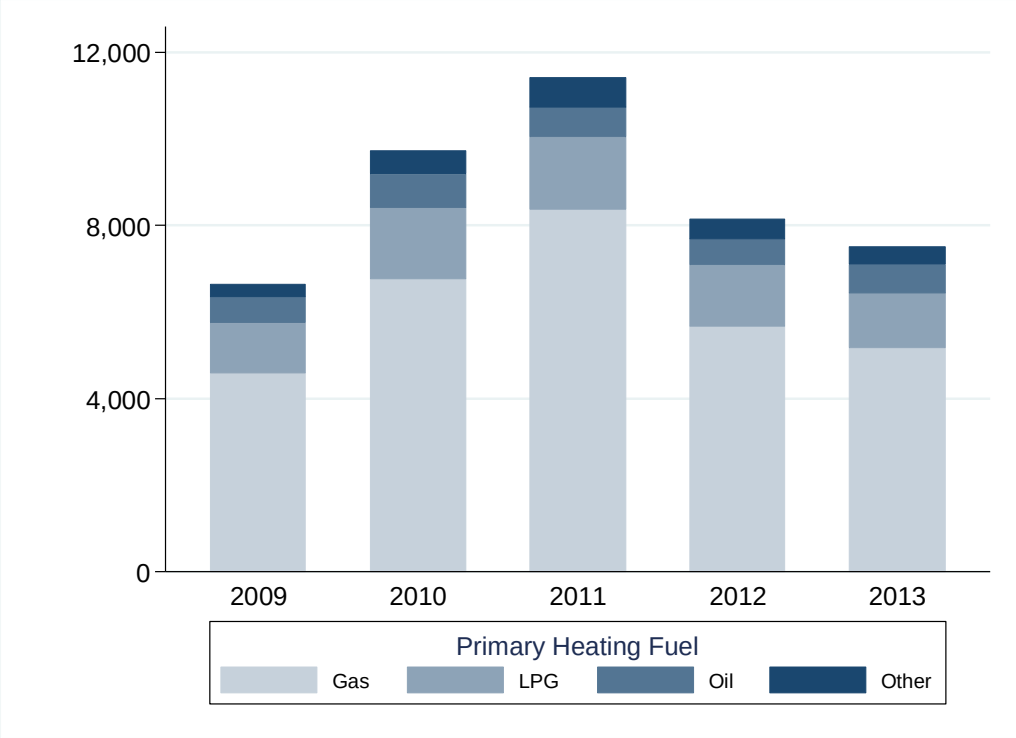
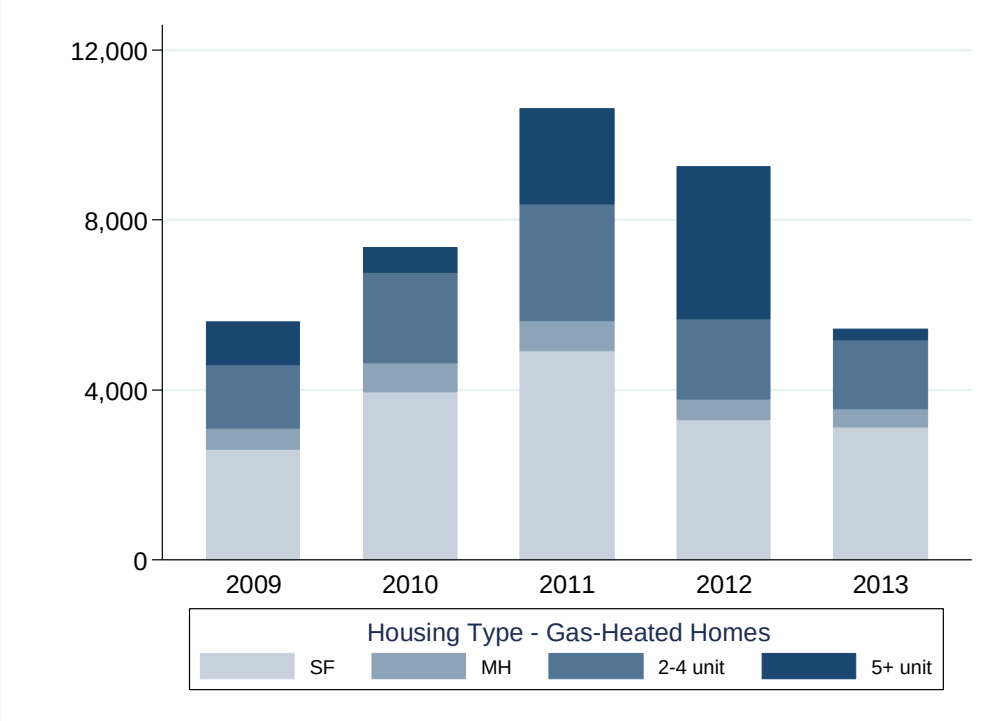


Figure 2. Number of gas-heated housing units treated by the program between FY09 and FY13.



2.0 Gas and Electricity Savings

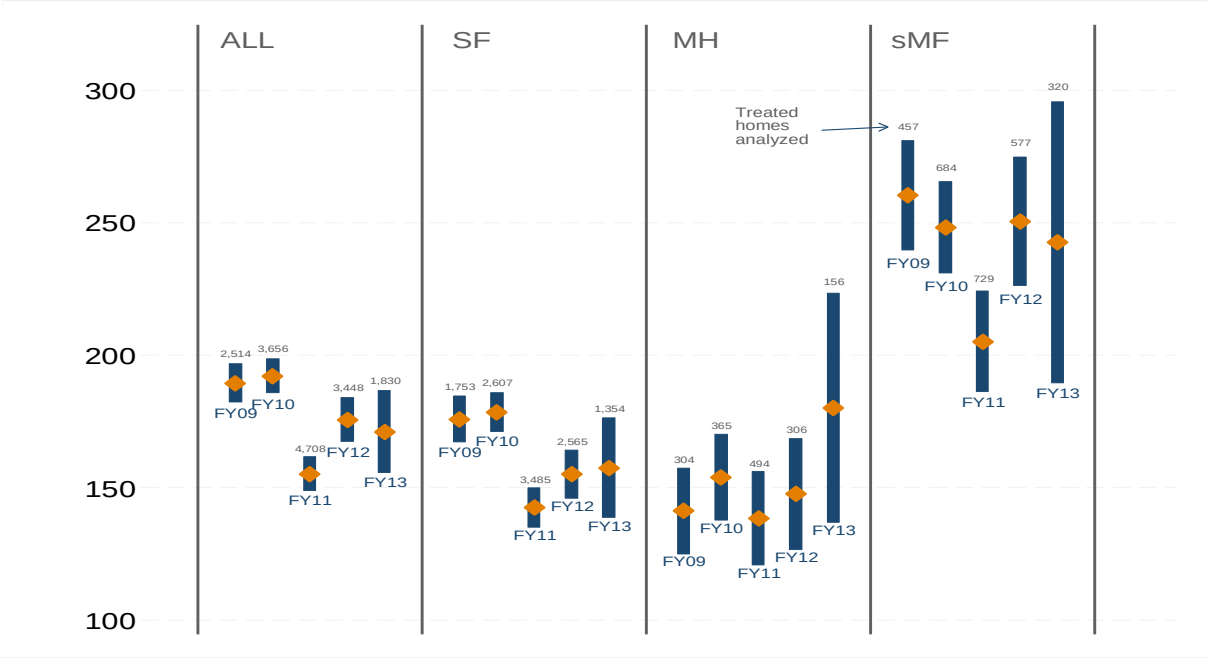
The scope of this analysis includes gas-heated housing units in 1-4 unit buildings. Gas savings for units in 1-4 unit buildings have typically ranged between 150 and 200 therms. Savings for mobile homes and single-family site-built homes are comparable, but on the lower end of this spectrum. Analyzed accounts for 2-4 unit structures, which are presumed to be predominately unit-level meters, show the highest savings. The majority of 2-4 unit buildings treated in the program are located in the Milwaukee and Racine metropolitan areas (about 67 percent in 2013), which are also the areas associated with the greatest gas savings in single-family, site-built homes.

2.1. Gas Savings

Annual therm savings were estimated for gas-heated homes treated between FY09 and FY13. Figure 3 shows savings estimates for single-family, site-built homes, mobile homes, homes in 2-4 unit buildings and a combined average for all homes in 1-4 unit buildings. Savings estimates for individual housing units are weighted so that the billing data sample more accurately reflects the actual mix of gas-heated homes treated by each agency within each housing type and fiscal year.

For each housing type and fiscal year, similarly weighted therm savings estimates of future participants are used to correct for non-programmatic effects and to further correct for errors in the weather-adjustment models. Future participant savings are also weighted so that comparison homes more accurately reflect the pre-weatherization usage levels of treated homes. In sum, the resulting savings estimates provided in Figure 3 accurately represent the statewide population of gas-heated homes treated in each fiscal year by building type, and are net of year-to-year changes in weather and any other non-programmatic effects.

Figure 3. Gas savings estimates for homes treated during FY09 through FY13. The blue vertical bars represent the 90% confidence interval around the mean savings estimate.

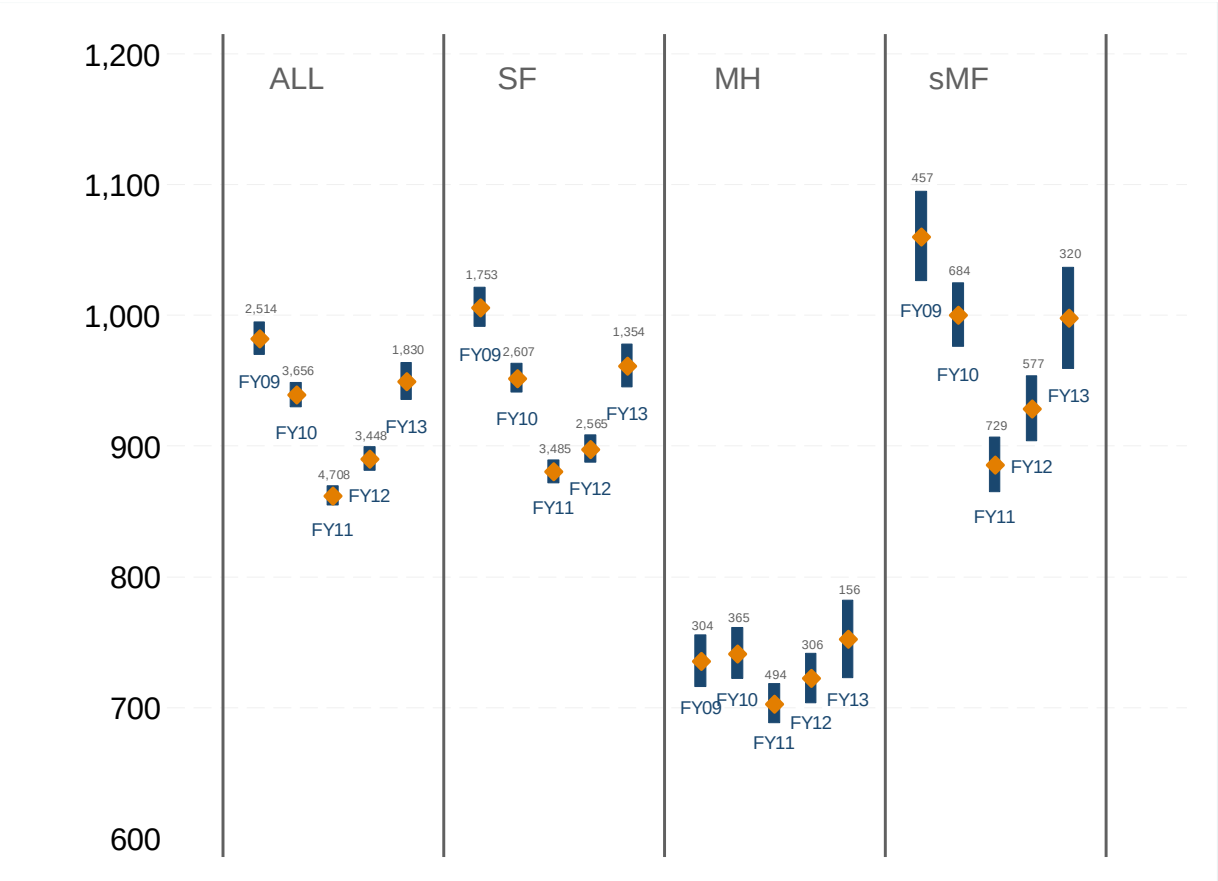


Single-family homes treated by the program in FY12 used 897 ±11 therms and saved 155 ±9 therms (or approximately 17 percent pre-weatherization usage). Fiscal year 13 results, which are relatively more uncertain due to a smaller and less complete comparison group, used 960 ±17 therms and saved 158 ±20 therms (or approximately 16 percent savings). The smallest amount of gas savings per treated housing unit was realized during FY11, which coincided with the ARRA period (Figure 1). Single-family homes treated during FY11 used 879 ±9 therms and saved 142 ±7 therms. Similar trends can be seen for both mobile homes and 2-4 unit buildings, as exhibited by the savings estimates and confidence intervals presented above in Figure 3.

Gas-heated housing units in all 1-4 unit housing types that were treated during FY12 used 880±10 therms and saved 176 ±9therms (or 20 percent of pre-weatherization usage). Results for homes treated in FY13 were similar and not statistically different from FY12: the average housing unit used 949 ±15 therms before being weatherized and saved 171 ±16 therms.

Therm savings for weatherized homes trend with pre-weatherization usage levels. Homes with higher usage typically have more opportunity for cost-effective energy conservation measures. Figure 4 shows how pre-weatherization gas usage has varied on a year-to-year basis throughout the analysis period. Homes that were treated during FY11 had the lowest average pre-weatherization usage values. FY13 pre-weatherization usage levels are similar to homes that were treated during FY09 and FY10, however, the net savings are lower. This could be related to the lower reference gas price used after FY10, which may have had an impact on the incidence of gas-saving measures. [1]

Figure 4. Pre-weatherization gas use in gas-heated homes.



[1] Homes audited in FY09 used a reference natural gas price of $1.50 per therm. Homes audited during FY09 were likely treated in either FY09 or FY10. The reference gas prices used during audits in FY10 through FY13 were all $1.00/therm or lower. All other things being equal, a higher reference gas prices necessarily results in larger bill savings, resulting in a greater range of cost-effective measures.

Therm savings for homes using similar amounts of natural gas before being weatherized have saved similar amounts of energy throughout the analyzed period (
Figure **5**). The highest users have realized the greatest savings (typically between 300 and 350 therms per year, on average). Not only do higher using homes save more gas in absolute terms, they also save a larger number of therms relative to their pre-weatherization usage (in percentage terms, as shown below in Figure 6.)

Figure 5. Therm savings in gas-heated single-family site-built homes by pre-weatherization usage bin.

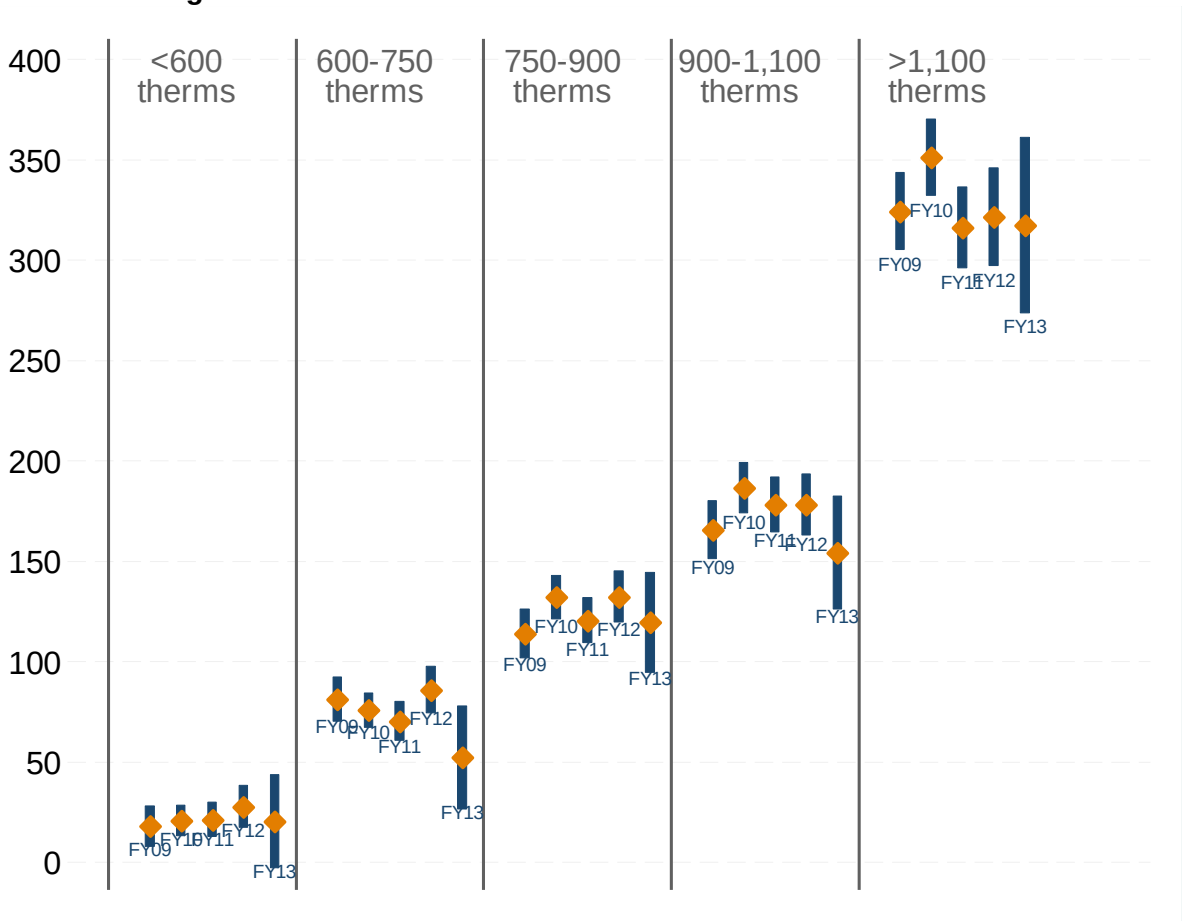
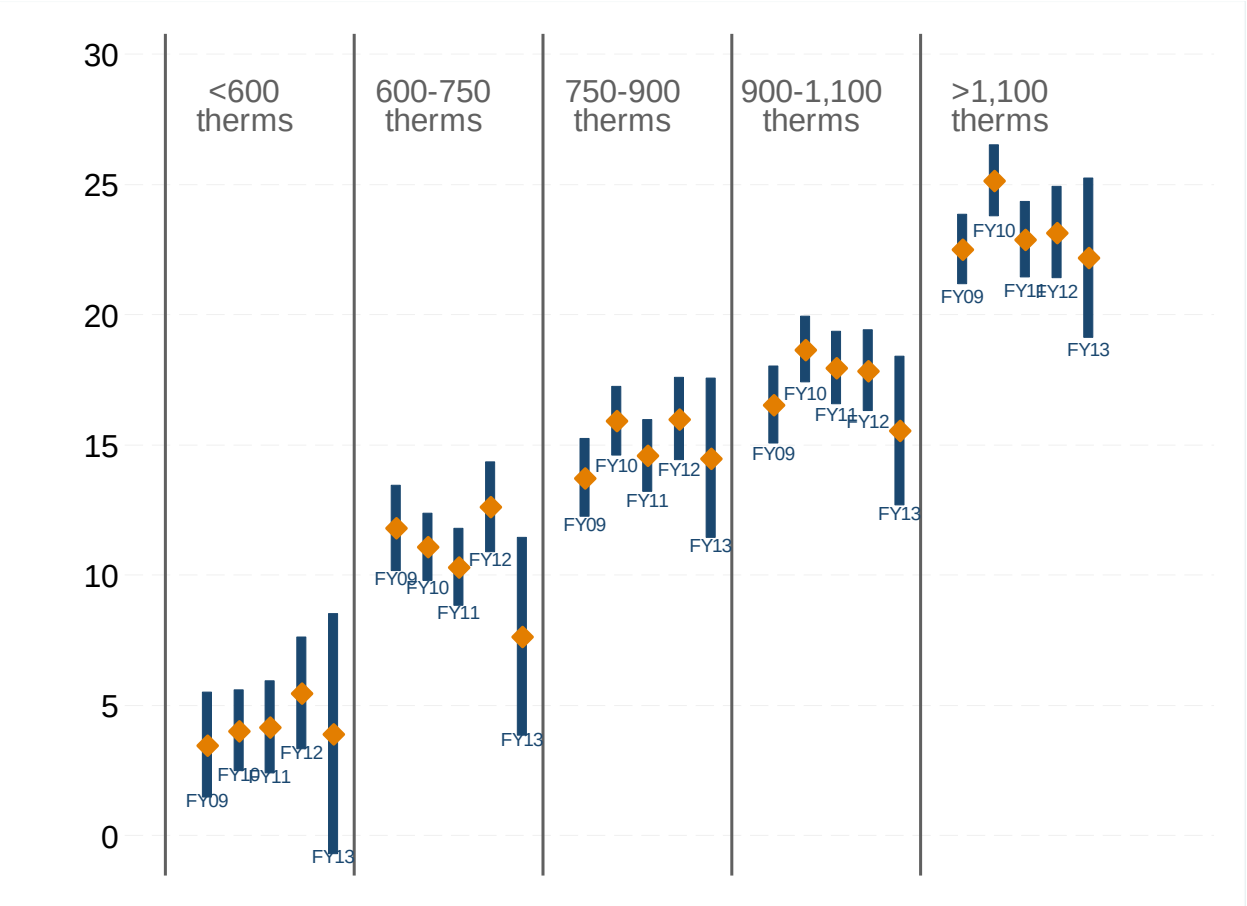


Figure 6. Gas savings as a percentage relative to pre-weatherization usage.

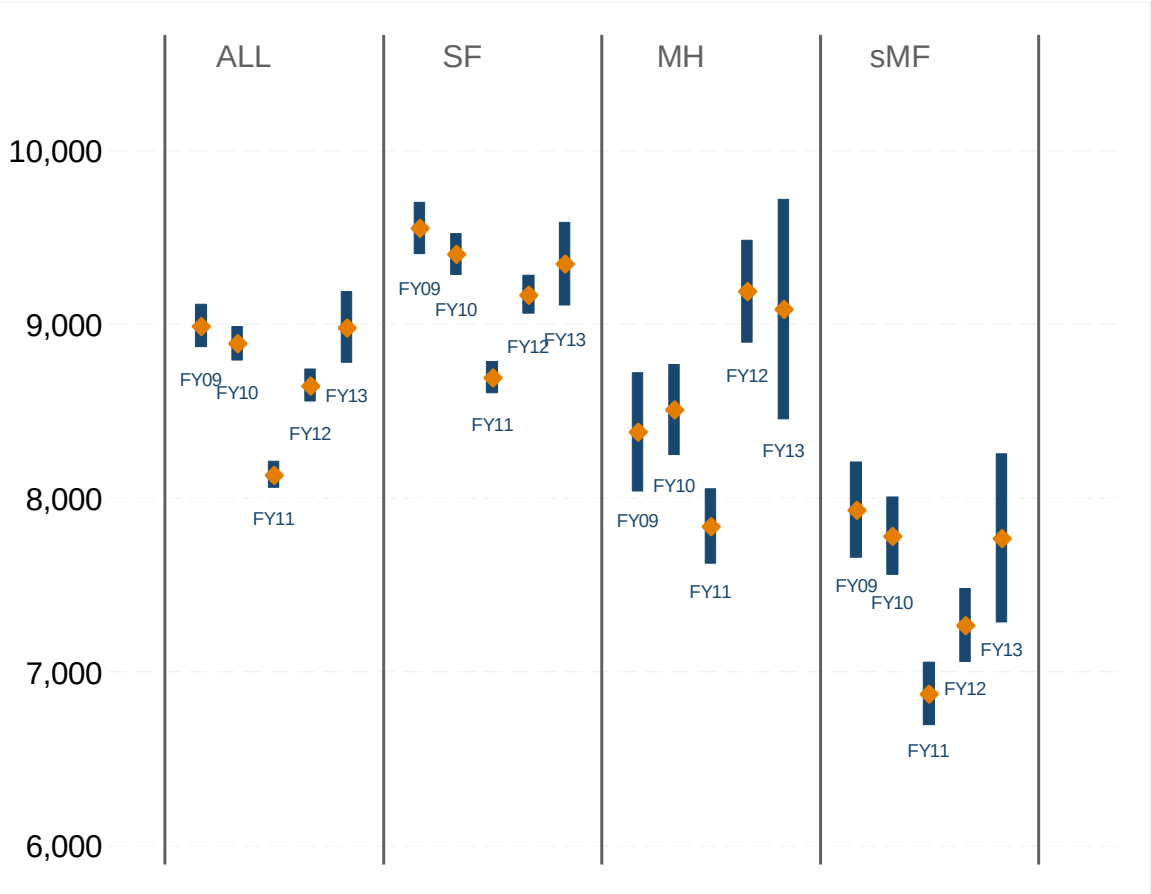


2.2. KWH Savings

Like pre-weatherization gas use, average pre-weatherization electricity use of homes treated by the program has varied during the FY09 to FY13 period (
Figure 7).

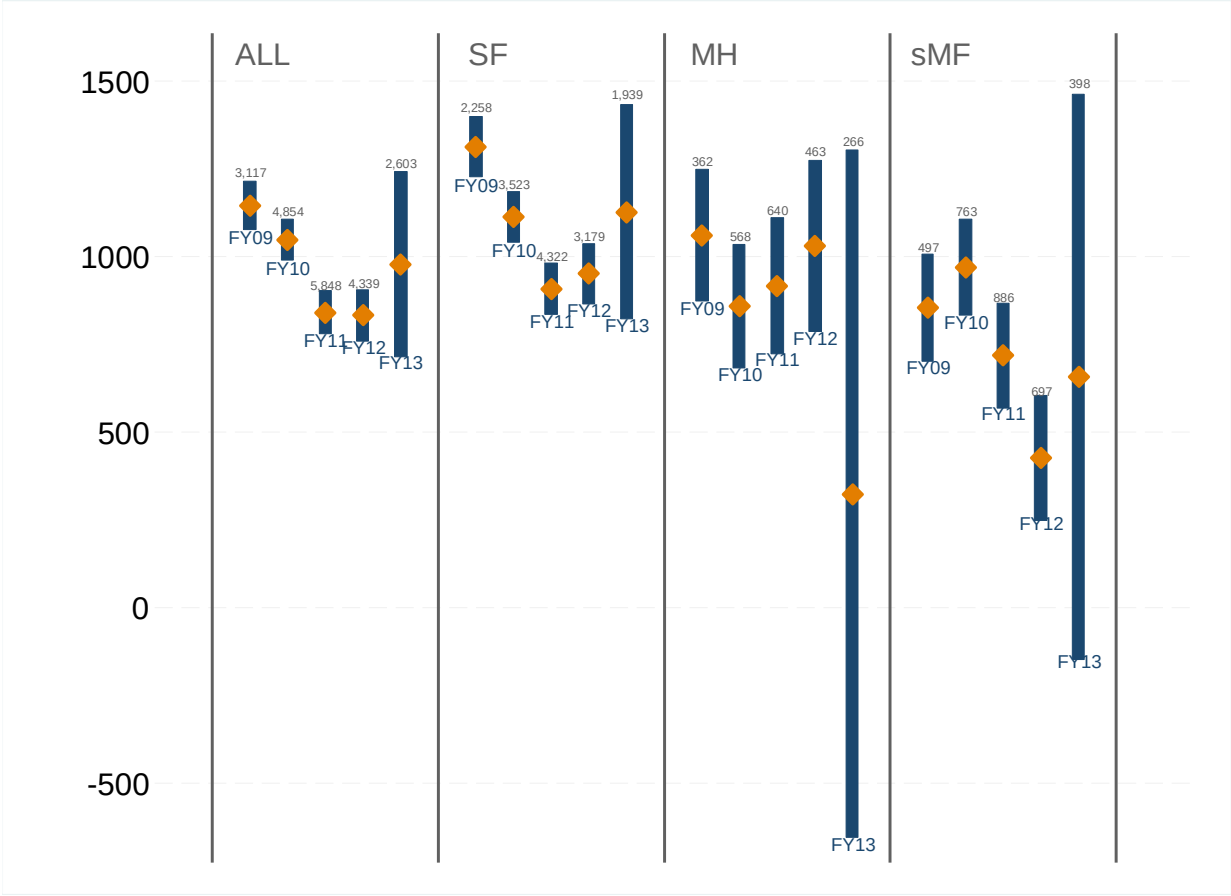
Figure 8 shows how electricity savings estimates have varied for homes treated by the program between FY09 and FY13. The 90 percent confidence intervals around the mean net savings estimates that are shown in Figure 8 for electricity are comparatively wider than those shown for gas savings in Figure 3. Mostly, the wider confidence intervals result because electricity use is much more variable on a year-to-year basis than is gas for most homes (there are many more end uses for electricity in the home and therefore more sources for variance). For FY13, fewer billing accounts were available for analysis for treated homes and future participants used for comparison which resulted in extremely uncertain savings estimates, especially for mobile homes and units in 2-4 unit buildings.

Figure 7. Pre-weatherization electricity use for 1-4 unit homes treated by the program from FY09 to FY13.



Given the lack of data for FY13, electricity savings are presented for FY12. Housing units in all 1-4 unit structures that were treated during FY12 saved 831 ±74 KWH which is approximately 10 percent of their pre-weatherization usage. Single-family and mobile homes have saved more on average than housing units in 2-4 unit buildings during the analysis window. This is partly because the incidence of electric to natural gas water heater conversions is much lower in 2-4 unit buildings. Single-family, site-built homes treated during FY12 saved 950 ±85 KWH/yr, or 10 percent of pre-weatherization levels. Mobile homes treated during FY12 saved a similar amount of electricity (1,028 ± 244 KWH/yr).

Figure 8. Electricity savings estimates for homes treated during FY09 through FY13. The blue vertical bars represent the 90% confidence interval around the mean savings estimate.

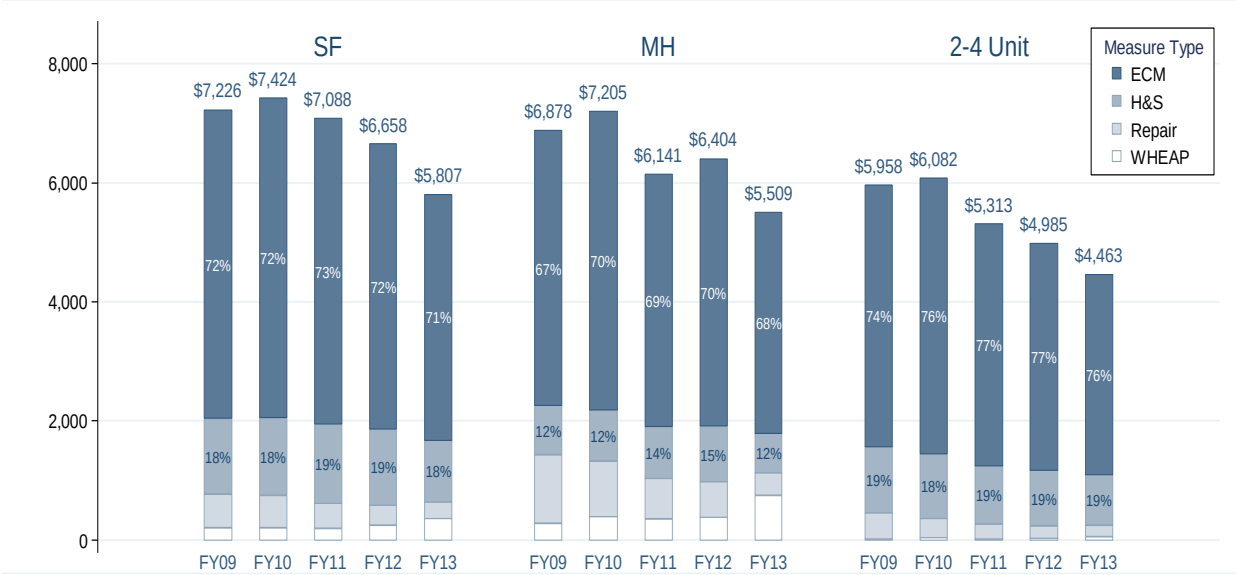


3.0 Per unit Spending and Measure Incidence

3.1. Average Spending per Housing Unit

The average amount spent per housing unit has steadily dropped since FY10. For single-family site-built homes, average spending per treated home has dropped over twenty percent between FY10 and FY13 (Figure 9). The drop in spending is likely related to several factors, including lower reference gas prices used in audits, an increased use of computerized audits overall (a policy requiring that computerized audits be run on 100 percent of jobs went into effect in FY12), and additional limits imposed on health and safety and repair spending.

Figure 9. Average spending per gas-heated housing unit, by fiscal year, housing type and measure type.



4.0 Measure Incidence

Changing gas prices, increased use of computerized audits and policy changes have contributed to changes in the incidence of major measures implemented in the program. These changes are evident in Table 1, which shows the incidence of selected measures and other characteristics for gas-heated single-family homes treated in each of the past five fiscal years. The change in incidences corroborates the drop in per-unit spending that was discussed in the preceding section.

The decrease in incidences of attic insulation, wall insulation and heating system replacements and an increase in the incidences of water heater fuel-switching measures partially explain why the FY13 per-unit therm savings estimates did not increase along with the average pre-weatherization usage during the same period. Incidences for some major insulation measures and heating system replacements were highest during FY09 and FY10, a time-period that corresponds with higher reference gas prices. In addition, the program should recognize that the incidence of WHEAP furnaces has been steadily increasing over the last five fiscal years, culminating in a 14 percent incidence rate among single-family gas-heated homes in FY13.

Table 1. Incidence of measures in single-family, gas-heated homes.

Description of Metric	FY09	FY10	FY11	FY12	FY13
Number of treated homes (gas heated, SF)	2,633	3,949	4,919	3,300	2,134
Incidence, All Attic	83%	85%	86%	86%	77%
Incidence, Unfloored	75%	75%	78%	78%	69%
Incidence, Unfloored (No existing)	14%	17%	14%	21%	21%
Incidence, Enclosed	32%	33%	32%	33%	30%
Incidence, Wall Insulation	40%	35%	31%	28%	28%
Ave SF Added, Wall Insulation	1,086	1,022	995	997	990
Incidence, All Replacements (w/ WHEAP)	59%	57%	51%	48%	45%
Incidence, All Replacements (w/out WHEAP)	53%	51%	45%	40%	34%
Incidence, Furnace, Energy Conservation	43%	40%	34%	28%	25%
Incidence, Furnace, Health and Safety	5.5%	5.2%	6.4%	7.8%	7.0%
Incidence, Boiler, Energy Conservation	4.7%	4.9%	4.0%	3.0%	1.8%
Incidence, Boiler, Health and Safety	0.8%	0.7%	0.9%	1.1%	0.4%
Incidence, DWH, Health and Safety	29%	34%	32%	28%	21%
Incidence, DWH, Fuel Switch	8%	7%	9%	10%	14%
Incidence, Refrigerator	43%	46%	42%	39%	37%
Incidence, Freezer	15%	16%	16%	14%	12%
Ave "As-is" Blower Door Reading	3,104	2,840	2,599	2,616	2,765
Ave "Post" Blower Door Reading	2,097	1,952	1,794	1,792	1,917
Ave Reduction, "As-is" to "Post"	1,050	933	824	841	875
Mechanical Ventilation	61%	62%	69%	72%	54%

5.0 Program SIRs

Average fuel savings and information on per-unit spending was used to estimate program savings to investment ratios (SIRs) for each housing type and fiscal year. SIRs for gas-heated homes are presented first, then SIRs for oil- and propane-heated homes, and finally a composite SIR for gas, oil and propane-heated homes combined.

Since pre- and post-weatherization fuel records for oil- and propane-heated homes were not analyzed directly for this report, the SIRs for these homes are only approximations. The basis for their SIRs are gas savings estimates, albeit with a significant amount of adjustment so that they better reflect the incidence of major measures that are installed in bulk fuel homes relative to homes that are heated using gas. These adjustments, along with other assumptions made when calculating the program SIRs are discussed below.

Two sets of SIRs are provided for each housing type. One set of SIRs is calculated using only energy conservation measure (ECM) and repair costs. The second set of SIRs adds health and safety costs, but excludes WHEAP furnace replacement costs. SIRs calculated with WHEAP furnace replacement costs included are provided in appendix A (see Table A 8).

5.1. Assumptions used in SIR Calculations.

Key assumptions related to the calculation of program SIRs are discussed below.

Fuel Prices. An average reference fuel price describing the four-year period was calculated for each fuel. Each year's price is weighted by the number of homes treated for each housing types and fiscal year. The historic fuel prices that were used are listed in the table below.

Fiscal Year	Electricity ($/KWH)	Gas ($/Therm)	Oil ($/Gal)	Propane ($/gal)
2009	$0.115	$1.50	$4.10	$2.80
2010	$0.125	$1.00	$2.29	$1.70
2011	$0.110	$1.00	$2.29	$1.80
2012	$0.117	$0.99	$2.69	$1.89
2013	$0.122	$0.93	$2.89	$2.00

Fuel Price Escalators. Fuel prices were adjusted using a set of fuel price escalators derived from the price indices being used in audits completed during FY13. For gas, a fuel cost escalator of 1.0 percent per year was used. The assumed fuel cost escalator for electricity was negative but close to zero (-0.2 percent per year). The fuel cost escalators used for propane and fuel oil were 1.4 percent and .7 percent, respectively.

Discount rate. Future savings were discounted at a rate of 3 percent per year.

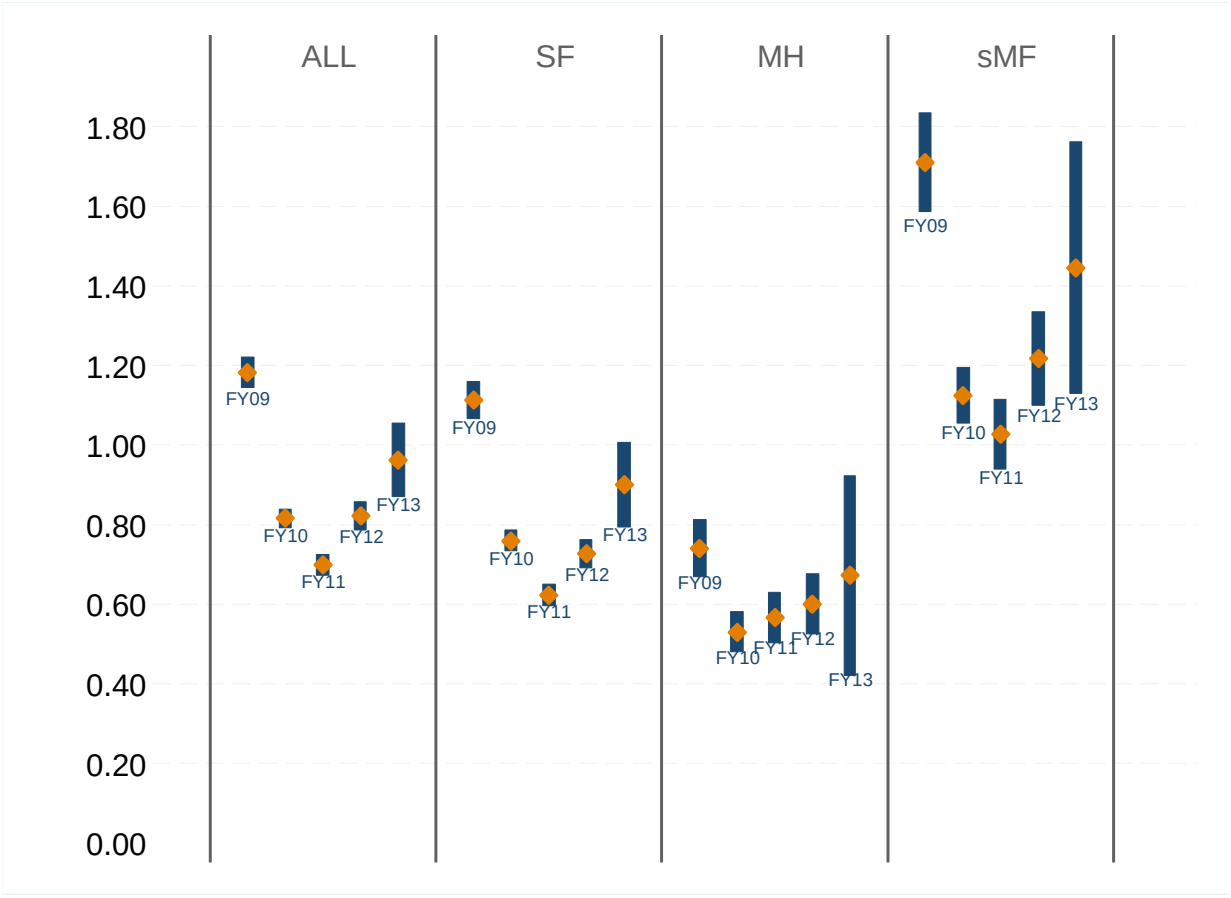
Measure life. Incidences of therm and electricity saving measures were used to calculate aggregated measure lives, which were then used to estimate the present value of future savings.[2] For site-built homes, the aggregated measure lives ranged between 27 and 30 years for gas, oil and propane and between 12 and 17 years for electricity. For mobile homes, the aggregated measure lives for each agency ranged between 19 and 20 years for gas, oil and propane and between 12 and 15 years for electricity. A weighted average of the aggregated measure lives of all three housing types was used to estimate the average combined SIR for housing units in all 1-4 unit buildings.

Figure 10 shows program-wide SIRs for gas-heated homes in 1-4 unit buildings that were treated between FY10 and FY13. The costs used to calculate the SIRs in Figure 10 include health and safety spending but not WHEAP furnace replacement costs.

Figure 10 include health and safety spending but not WHEAP furnace replacement costs.

[2] Measure life assumptions for measures in site-built homes are longer than what the program currently uses in NEAT audits. The SIRs presented here for site-built homes assume a life of 35 years for insulation measures and 25 years for heating system replacements. Measure life assumptions for mobile homes are close to the measure lives that the program uses to model potential jobs in MHEA. Differences between measure life assumptions in site-built and mobile homes stem from a lower life expectancy for mobile homes.

Figure 10. Program-wide SIRs for gas-heated homes, by fiscal year and housing type.

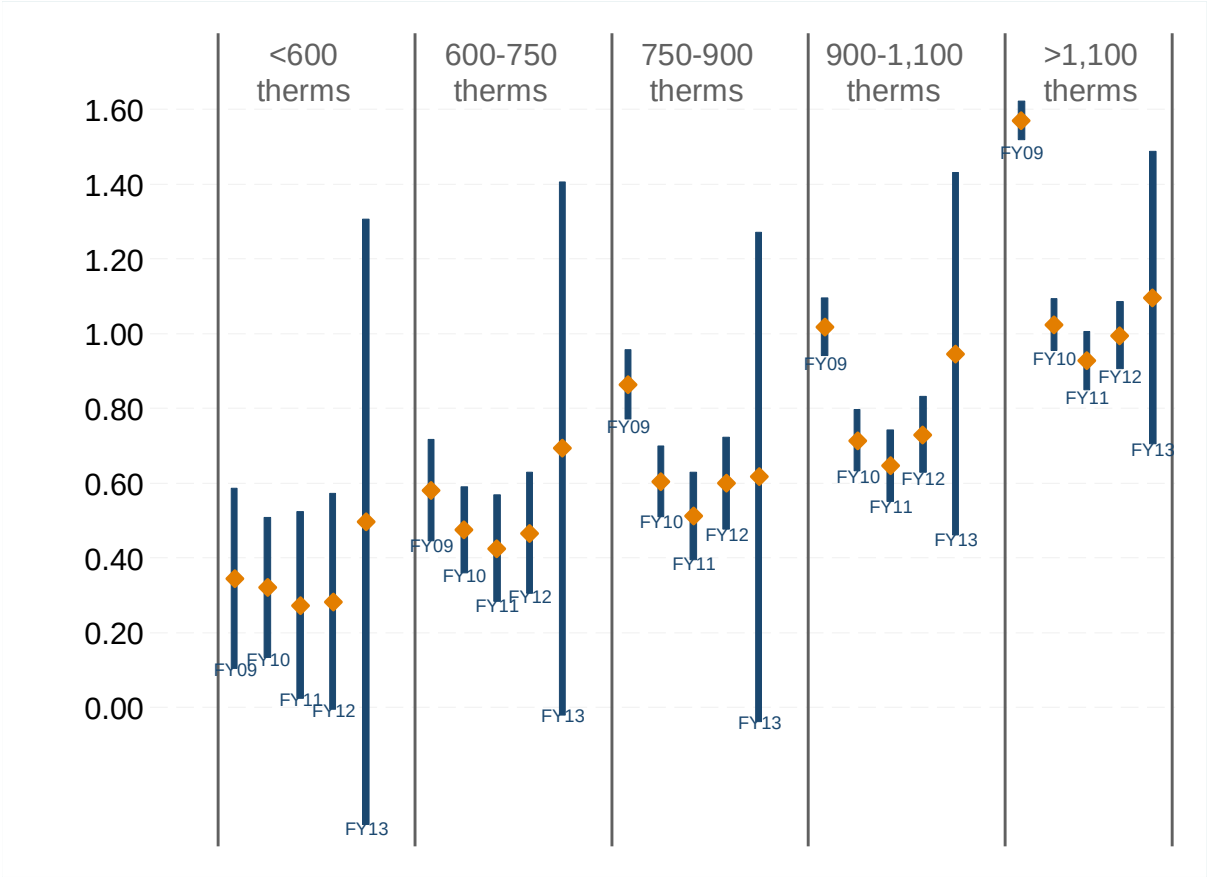


5.2. SIRs for different quintiles of pre-weatherization usage

As shown in Figure 6, therm savings are higher in both absolute and relative terms, for homes that used more gas before being weatherized. Because higher-using homes receive more weatherization measures, per unit spending for these homes is higher as well. Savings increase at a proportionately higher rate than costs with each successive quintile of pre-weatherization usage. As a result, SIRs tend to be higher for higher using homes.

Figure 11 shows program-wide SIRs for gas-heated homes by quintile of pre-weatherization gas consumption and fiscal year in which the home was treated. Costs used to calculate the SIRs include health and safety spending but not WHEAP furnace replacement costs. The SIRs generally increase with each successive fuel usage bin (Figure 11).

Figure 11. Program-wide SIRs for gas heated single family homes, by fiscal year and housing type.



5.3. SIR Approximations for Bulk Fuel Homes

The SIRs for bulk fuel homes are only approximations because pre- and post-weatherization fuel records for oil- and propane-heated homes were not analyzed directly for this report. Gas savings estimates were adjusted to calculate SIRs for these homes. The adjustments made to develop these SIRs are described below.

Approximating bulk fuel savings using gas savings estimates. Program gas savings are used to approximate the annual bill savings for propane and oil heated homes. It's reasonable to assume that the incidence of major measures in oil- and propane-heated homes would be different than in gas homes because the current reference prices for bulk fuels are higher; therefore, more measures can be justified on the basis of cost-effectiveness. In addition, housing stock differences, such as the average year that oil- or propane-heated homes were built, may also influence how frequently certain measures are installed.

For these reasons, incidence rates of major measures in oil- and propane-heated homes are used to adjust gas savings to better reflect the MMBTU savings that may likely be achieved in homes heated using bulk fuels. The major measures used for the adjustment include, but are not limited to, attic and wall insulation, heating system replacement and water heater fuel switching measures. Adjustment factors consider both the incidence of these measures and their relative impact when installed.

Electricity savings estimates are also adjusted to reflect the relative differences in the incidence of water heater fuel switching measures in propane- and oil-heated homes. This is necessary because more electric water heaters are switched to a different heating fuel in oil-heated homes than in gas- and propane-heated homes.

Oil to gas heating fuel switching. The program does not directly track oil to natural gas fuel switching measures. An examination of collected energy audits shows that some agencies replace oil-fired space heating systems in oil homes quite frequently. Natural gas furnace replacement and electric to natural gas water heater fuel switching measure codes were used to identify the oil-heated homes in WisWAP that most likely switched to using natural gas as the primary heating fuel. An average annual savings for oil to gas fuel switching was approximated by multiplying the incidence of these measures by the average post-weatherization gas use for each housing type and the difference between the prices for oil and gas. The discounted net present value of these savings were then added to the net present value of expected savings from weatherization to get an average SIR for oil-heated homes for each housing type.

Table 2 provides program-wide SIR estimates for gas-, oil- and propane-heated homes that were treated during FY13. Both SIRs and job costs for oil-heated homes are significantly higher than for other fuels.

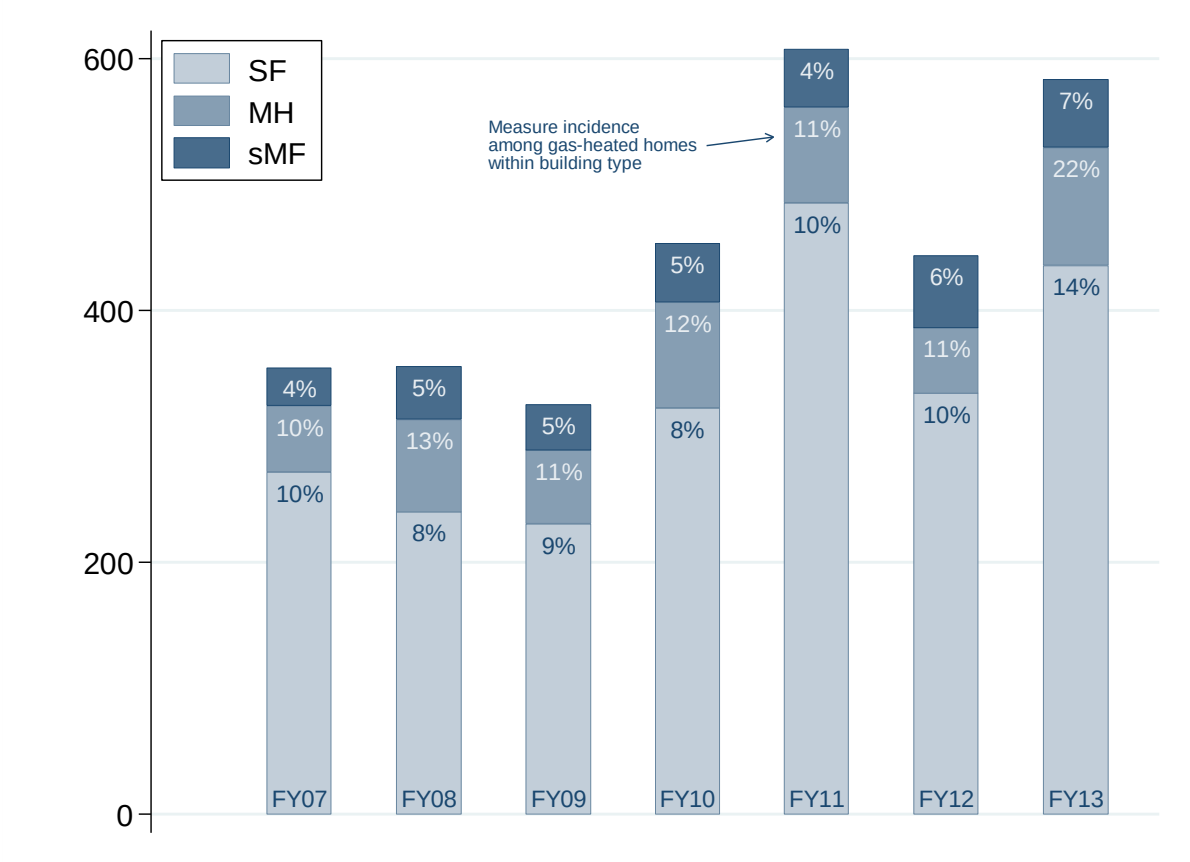
Table 2. Average SIRs (with 90% confidence intervals) and job costs for homes treated during FY13. SIRs for oil- and propane-heated homes are approximations based on electricity and therm savings estimates for gas-heated homes and a set of adjustments.

Housing Type	Heating Fuel	With Health and Safety		No Health and Safety	
		SIR	Ave Job Cost ($)	SIR	Ave Job Cost ($)
All 1-4 Unit	Combined	1.43 ± 0.11	$5,368	1.73 ± 0.13	$4,437
	Gas	0.96 ± 0.09	$5,061	1.18 ± 0.11	$4,111
	LPG	1.92 ± 0.17	$5,630	2.29 ± 0.20	$4,716
	Oil	2.94 ± 0.14	$6,938	3.34 ± 0.16	$6,108
Single-Family, Site-Built	Combined	1.37 ± 0.13	$5,713	1.66 ± 0.16	$4,704
	Gas	0.90 ± 0.11	$5,439	1.11 ± 0.13	$4,396
	LPG	1.68 ± 0.19	$5,798	2.03 ± 0.22	$4,795
	Oil	2.89 ± 0.17	$7,015	3.28 ± 0.19	$6,179
Mobile Home	Combined	1.29 ± 0.32	$4,982	1.49 ± 0.37	$4,304
	Gas	0.67 ± 0.25	$4,768	0.78 ± 0.29	$4,108
	LPG	1.97 ± 0.48	$5,164	2.27 ± 0.55	$4,476
	Oil	1.87 ± 0.45	$7,052	2.17 ± 0.53	$6,081
2-4 Unit	Combined	1.59 ± 0.33	$4,467	1.96 ± 0.40	$3,622
	Gas	1.44 ± 0.32	$4,402	1.79 ± 0.39	$3,553
	LPG	2.57 ± 0.51	$6,225	2.96 ± 0.58	$5,410
	Oil	4.70 ± 0.49	$5,881	5.35 ± 0.55	$5,163

6.0 Water Heater Fuel Switching

Stable electricity and falling gas prices have led to increasingly favorable conditions for water-heater fuel-switching measures. As seen in Figure 12, this has translated to a recent uptick in the incidence of water heater fuel-switching measures for homes treated during FY13. Below, gas and electricity savings are presented for homes treated during FY12 (there was insufficient comparison group data and data describing homes that fuel-switched to analyze FY13 homes)

Figure 12. Incidence of water heater fuel switching measures among gas-heated homes.



Although there are multiple measures that result in a savings penalty when installed (and discussed later in the measure-level analysis of this report), water heater fuel switching is the measure associated with the largest penalties when installed. Furthermore, the incidence of water heater fuel switching measures varies significantly across agencies (between 0 and 26 percent for single-family homes treated during FY12). For this reason, it's important to quantify the impact of gas to electric fuel switching measures on average therm and KWH savings.

Table 3. Net KWH and Therm Savings Estimates for Single-family homes treated during FY12.

Fuel	Condition	Units Analyzed	Pre-Wx Usage	Net Savings	Percent Savings
Electricity (KWH)	Both	3,179	9,165 ±114	965 ±86	11% ±1%
	w/ Fuel Switch	256	10,431 ±413	3,025 ±318	29% ±3%
	No Fuel Switch	2,923	9,050 ±118	780 ±85	9% ±1%
Gas (therms)	Both	2,565	897 ±11	154 ±9	17% ±1%
	w/ Fuel Switch	214	721 ±32	35 ±27	5% ±4%
	No Fuel Switch	2,351	912 ±12	165 ±10	18% ±1%

7.0 Overall Energy Savings

Annual therm and electricity savings for the program were calculated using the savings estimates and the number of completed units for each fiscal year. Heating fuel savings were estimated for each bulk fuel by adjusting the natural gas savings estimate according to the incidence of major measures for each heating fuel, relative to the incidence of measures in gas-heated homes (this is the same method that was used to extend natural gas savings to fuel oil and propane when evaluating cost-effectiveness).

A similar adjustment was made to electricity savings for oil- and propane-heated homes to account for differences in the incidence of electric to gas water heater fuel switching measures (and to a lesser extent, the differences in the incidence of refrigerator and freezer replacements). Table 4 lists aggregated heating fuel, electricity and combined savings for each fiscal year analyzed.

Table 4. Aggregate energy savings in treated 1-4 unit buildings, by fiscal year.

Fiscal Year	Treated Units	Aggregate Heating Fuel Savings (Billion BTU/Year)		Aggregate KWH savings (MWh/Year)		Aggregate Energy Savings (Billion BTU/Year)	
FY09	6,646	122	± 5	7,582	± 454	148	± 5
FY10	9,719	183	± 6	9,750	± 569	216	± 6
FY11	11,415	180	± 8	9,438	± 719	212	± 8
FY12	8,148	147	± 7	6,381	± 607	169	± 7
FY13	7,504	143	± 14	7,653	± 1933	169	± 15

8.0 Savings by Major Measure

One accessible means to compare gas savings across homes treated in the program is to evaluate the amount of savings that are typical for homes receiving any one of four major gas-saving weatherization measures. Single family and mobile homes were identified as having received a major gas saving measure if any of the following criteria were met.

- Attic insulation. Homes where at least 750 square feet of insulation was added to an attic having less than an average of R12 of existing insulation.
- Wall insulation. Homes where at least 500 square feet of sidewall insulation was added.
- Air sealing. Homes where air leakage rates were reduced by at least 750 CFM_{50} from the “As-is” to “Post” blower door test.
- Heating system replacement. Homes that had a furnace or boiler replaced as an energy conservation measure.
- Mobile home belly insulation. Mobile homes that receiving at least 500 square feet of insulation, which is virtually all mobile homes that get the measure.
- Mobile home roof insulation. Mobile homes that get at least 500 square feet of roof insulation.

An analysis of savings and measure incidences for 9,769 gas-heated homes shows that homes typically save on the order of 100 additional therms for each additional major measure that is installed. Nearly 30 percent of the gas heated single family homes treated by the program between FY10 and FY13 didn’t receive one measure that met the major measure criteria described above. **Error! Reference source not found.** and **Error! Reference source not found.** provide detailed information about the savings, pre-weatherization usage, job cost and the fraction of homes in each major measure category.

Figure 13. Savings and the fraction of gas heated single-family homes receiving major gas saving measures. Letter combinations in the plot below represent the mix of major measures installed, per the definitions provided above. "A" indicates attic insulation, "W" indicates sidewall insulation, "S" indicates air sealing and "H" indicates heating system replacement.

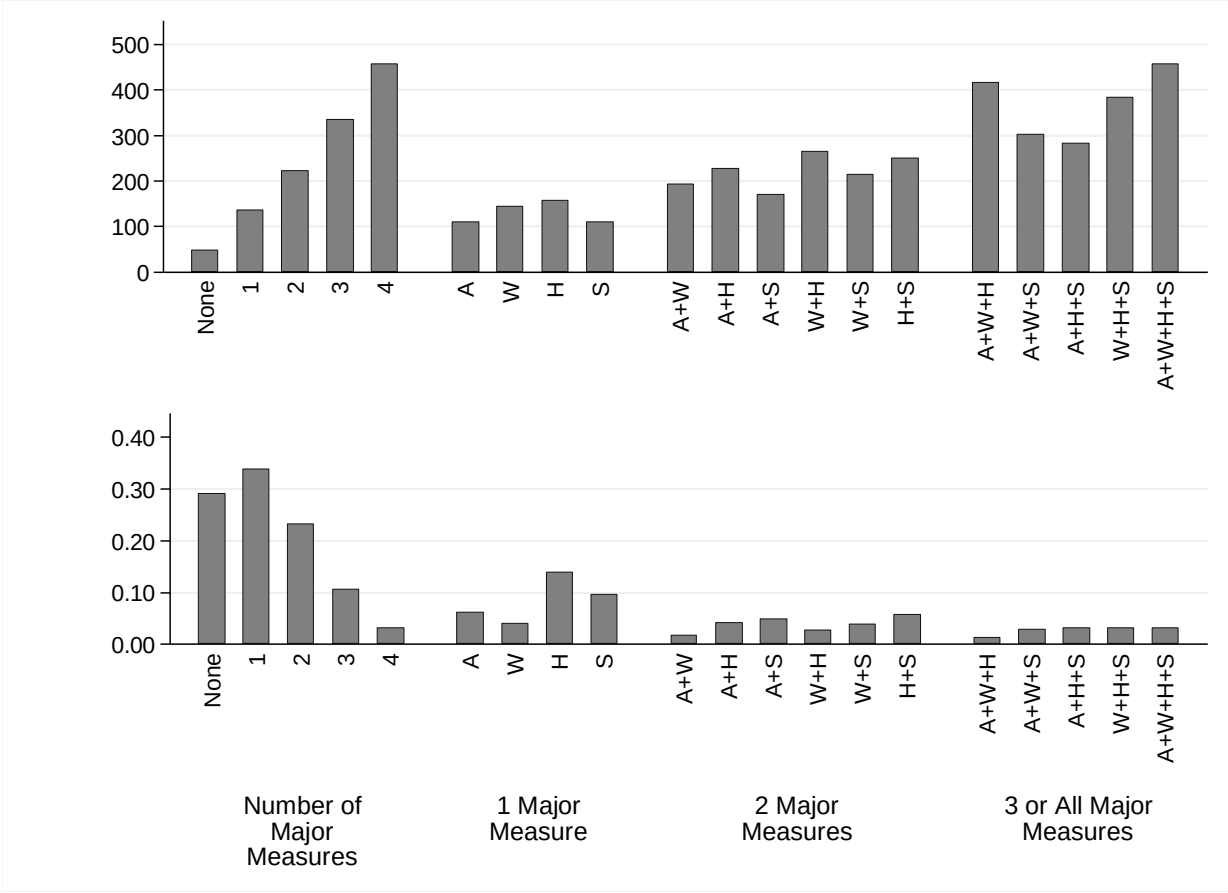


Table 5. Average savings by major measure category for gas heated single family homes treated between FY10 and FY13.

Measure Combination	Savings (therms)	Pre-Wx Usage (therms)	Unit Cost ($/job)	% of Homes
None	48 ± 4	782	$4,524	29%
1 Maj Meas	137 ± 13	880	$6,208	34%
2 Maj Meas	223 ± 17	992	$7,889	23%
3 Maj Meas	336 ± 16	1125	$10,016	11%
4 Maj Meas	457 ± 27	1254	$12,162	3%
A	110 ± 10	860	$5,768	6%
S	145 ± 13	831	$7,102	4%
W	158 ± 7	882	$6,664	14%
H	111 ± 8	891	$5,813	10%
A+W	194 ± 25	929	$8,479	2%
A+S	227 ± 17	1002	$7,929	4%
W+S	171 ± 13	968	$6,714	5%
A+H	264 ± 22	970	$9,361	3%
H+S	215 ± 16	983	$8,544	4%
W+H	250 ± 15	1025	$7,906	6%
A+H+S	416 ± 45	1176	$11,538	1%
A+W+S	302 ± 21	1125	$10,018	3%
W+H+S	284 ± 22	1093	$9,112	3%
A+W+H	385 ± 24	1135	$11,014	3%
A+W+H+S	457 ± 27	1254	$12,162	3%

Measure Key: “A” = attic insulation , “W” = sidewall insulation, “S” = air sealing, “H”=heating system replacement

A similar analysis was conducted for 1,288 gas heated mobile homes that were treated between FY10 and FY13. Almost all mobile homes get at least one major measure since most treated homes get at least 500 square feet of belly insulation. **Figure 14** shows that most homes getting just one major measure save about 85 therms on average. Roughly speaking there appears to be an additional 80 therms of savings for each additional major measure. A savings estimate, average pre-weatherization gas use, job costs and the fraction of mobile homes getting each combination of major gas saving measures is provided in

Table 6.

Figure 14. Savings by major measure category, gas heated mobile homes. Letter combinations in the plot below represent the mix of major measures installed, per the definitions provided above. "R" indicates fiberglass roof insulation, "B" indicates fiberglass belly insulation, "S" indicates air sealing and "H" indicates heating system replacement.

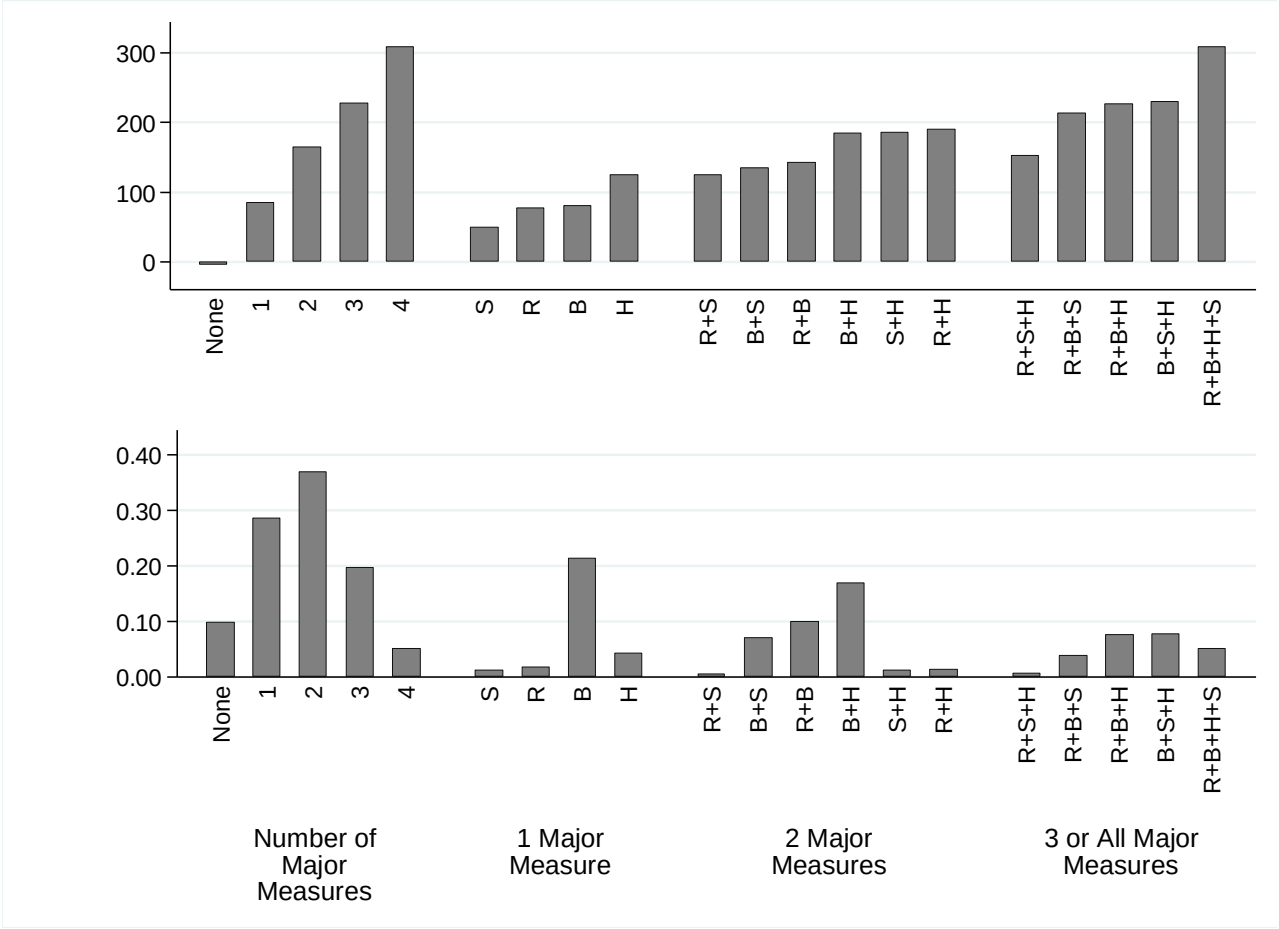


Table 6. Savings, pre-weatherization usage, unit cost and incidence of major gas saving measures in mobile homes treated from FY10 to FY13.

Measure Combination	Savings (therms)	Pre-Wx Usage (therms)	Unit Cost ($/job)	% of Homes
None	-5 ± 17	629	$3,056	10%
1 Maj Meas	85 ± 4	659	$4,832	29%
2 Maj Meas	165 ± 7	724	$6,553	37%
3 Maj Meas	228 ± 23	802	$7,797	20%
4 Maj Meas	309 ± 42	870	$9,333	5%
R	78 ± 39	677	$3,996	2%
B	81 ± 12	648	$4,869	21%
H	125 ± 26	699	$5,415	4%
S	50 ± 70	648	$4,905	1%
R+B	142 ± 18	685	$5,428	10%
R+H	190 ± 70	755	$6,863	1%
R+S	125 ± 35	745	$5,212	1%
B+H	185 ± 16	720	$7,622	17%
B+S	135 ± 23	744	$6,469	7%
S+H	186 ± 45	841	$6,958	1%
R+B+H	227 ± 25	746	$7,454	8%
R+B+S	214 ± 37	845	$6,865	4%
R+S+H	153 ± 66	768	$7,886	1%
B+S+H	231 ± 28	831	$8,840	8%
R+B+H+S	309 ± 42	870	$9,333	5%

Measure Key: “B”= fiberglass belly insulation , “R” = fiberglass roof insulation, “S” = air sealing, “H”=heating system replacement

9.0 Measure Analysis

Statistical regression analysis was used to estimate the average savings associated with individually installed measures. See Appendix B – Measure Analysis for a more detailed account of the methodology and analysis that underlies these savings estimates.

Following are gas savings estimates for measures installed in single-family site-built homes and mobile homes and overall electric savings estimates.

9.1. Single-family gas savings

The analysis for single-family site-built homes shows that the largest gas savings come from heating system replacements and wall and ceiling insulation (Figure 15 and Figure 16). Additionally, three measures that save electricity (water heater fuel switching, CFLs and refrigerator replacements) and one health and safety measure (mechanical ventilation) significantly increase gas consumption.

Figure 15. Measure contributions to gas savings in single-family site-built homes.

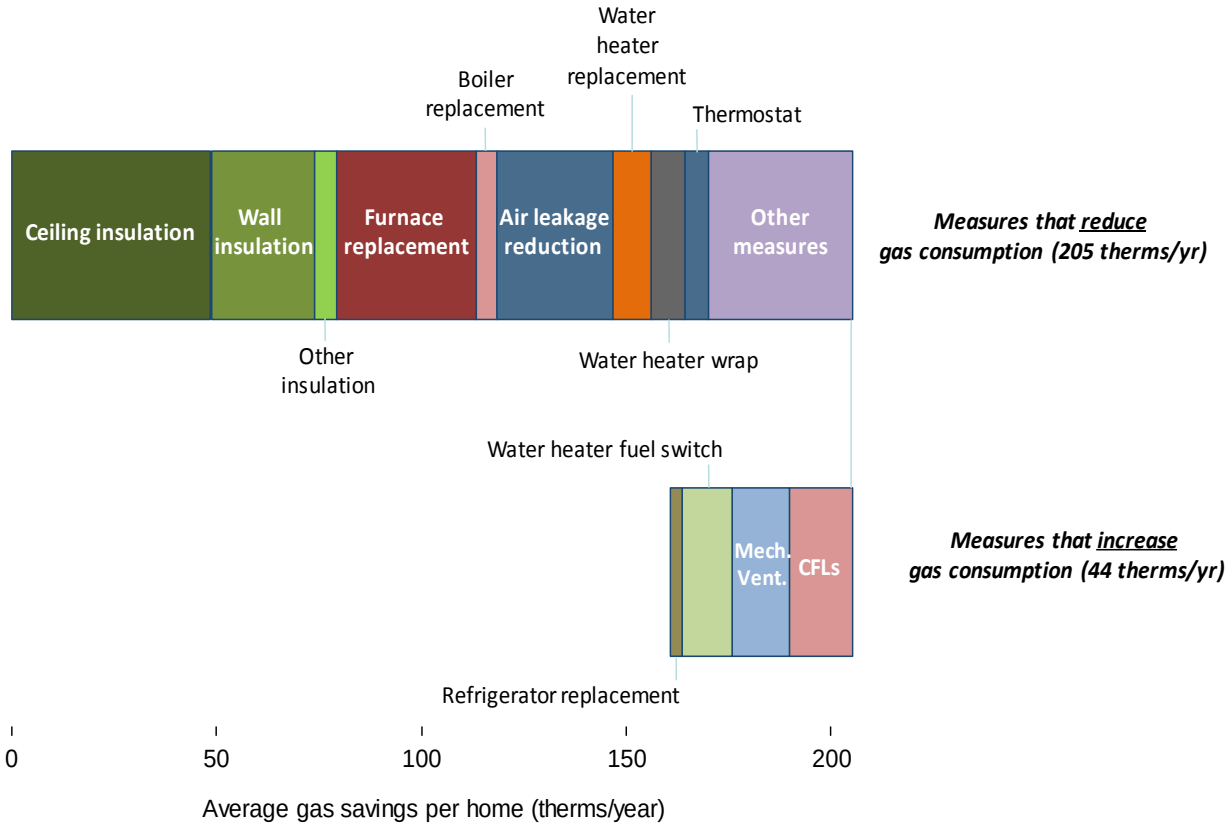
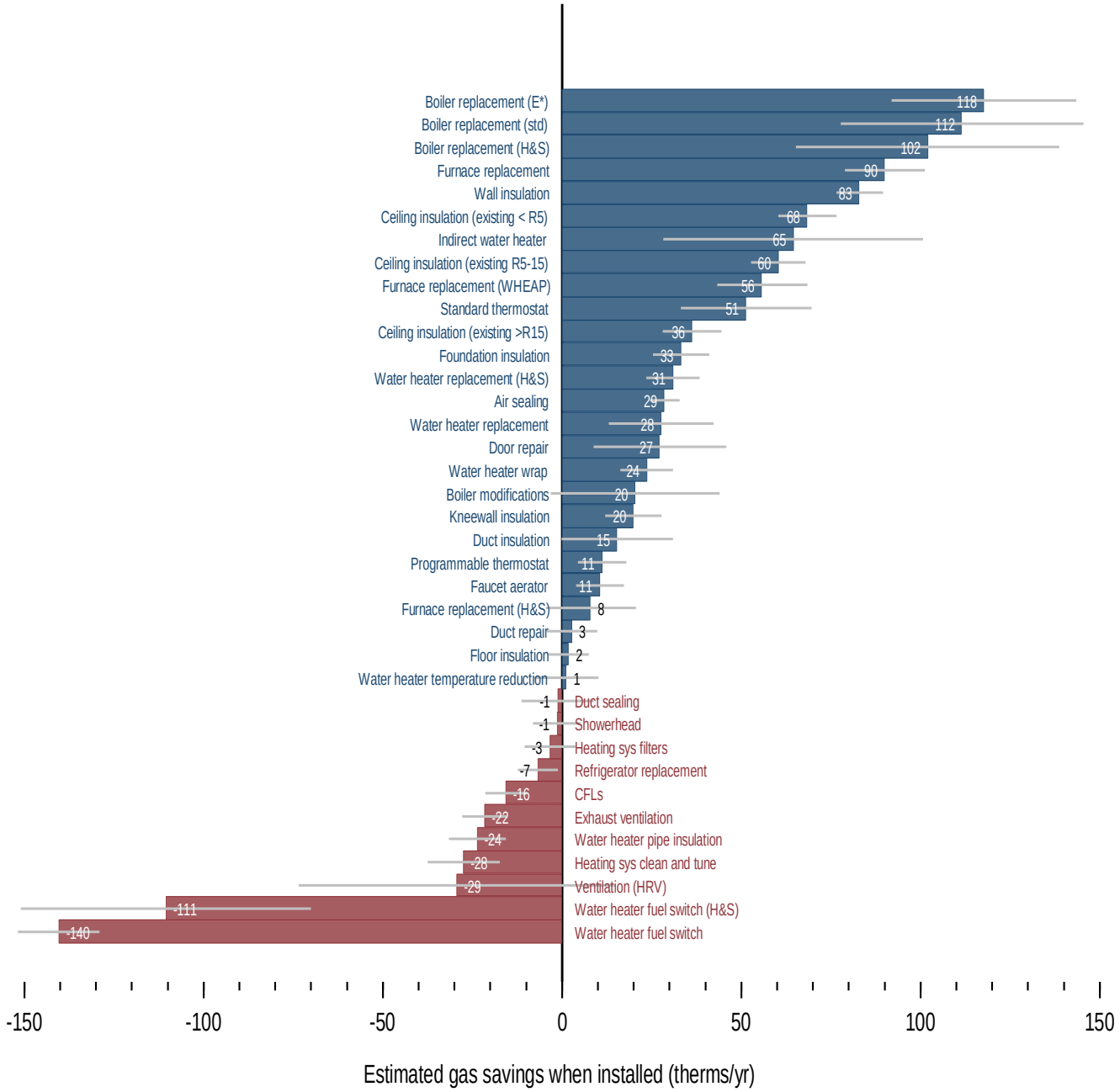


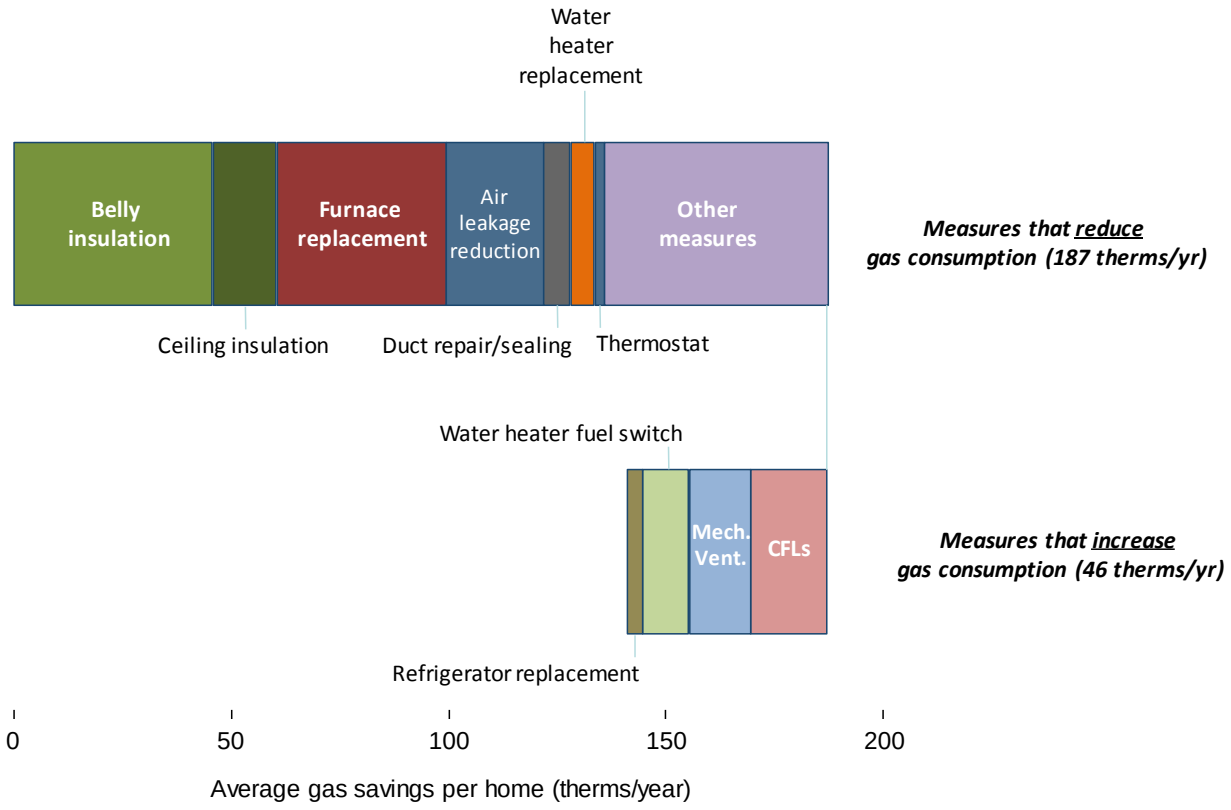
Figure 16. Average gas savings, when measure installed in gas-heated single-family homes.



9.2. Mobile home gas savings

Similar to single-family site-built homes, the largest gas savings for mobile homes come from furnace replacements and insulation (belly and ceiling). Water heater fuel switching, CFLs, refrigerator replacement and mechanical ventilation, while saving electricity, significantly increase gas consumption (Figure 17).

Figure 17. Measure contributions to gas savings in mobile homes.



9.3. Electricity savings

The analysis of electricity savings shows that water heater fuel switching saves the most electricity by far. Water heater, refrigerator and/or freezer replacement provide the next largest savings (Figure 18). Additionally the analysis found two measures (heating system replacements and mechanical ventilation) that significantly increased electricity consumption (Figure 19).

Figure 18, Average electricity savings, when installed.

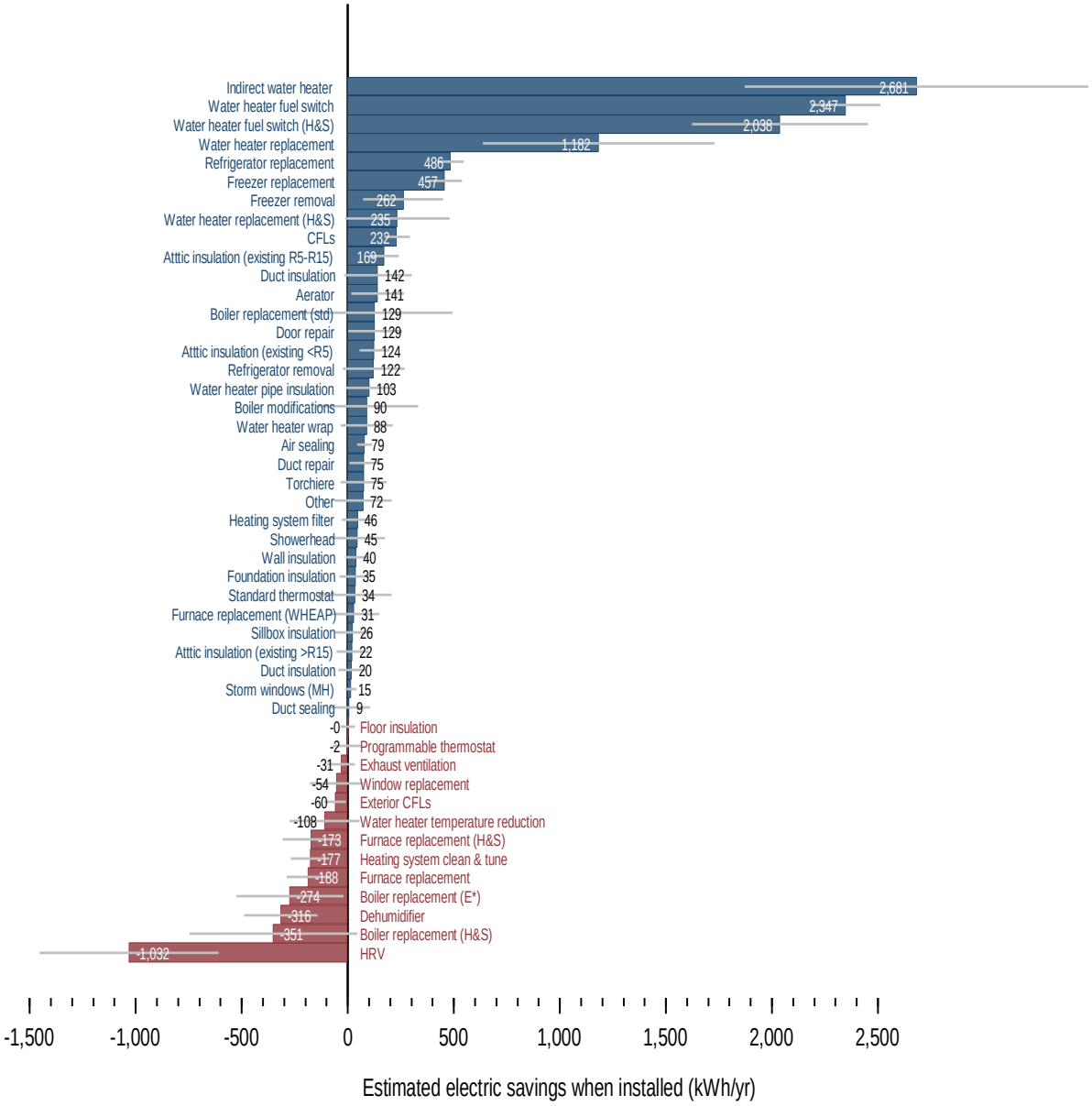
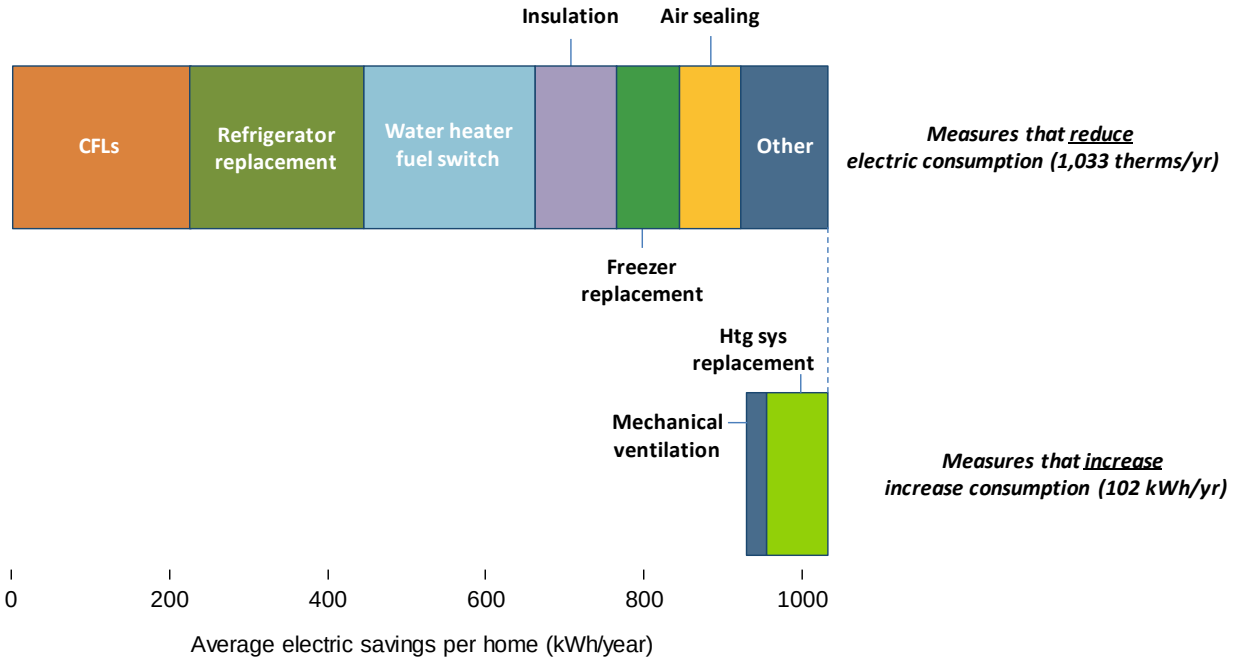


Figure 19. Overall contribution of measures to overall electricity savings.



Appendix A – Detailed Supporting Tables

Table A 1. Gas savings per housing unit for gas-heated homes in 1-4 unit buildings

Fiscal Year	Housing Units in 1-4 Unit Buildings			
	Pre-Wx Usage	Net Savings	Net % Savings	Units Analyzed
2009	979	190 ± 10	19 ± 1%	2,627
2010	936	195 ± 9	21 ± 1%	3,770
2011	861	155 ± 7	18 ± 1%	4,708
2012	889	175 ± 8	20 ± 1%	3,448
2013	948	171 ± 15	18 ± 2%	1,830

Table A 2. Gas savings per housing unit for gas-heated homes, by building type.

Fiscal Year	Single-Family, Site Built			Mobile Home			2-4 Unit		
	Pre-Wx Usage	Net Savings	Net % Savings	Pre-Wx Usage	Net Savings	Net % Savings	Pre-Wx Usage	Net Savings	Net % Savings
2009	1,003	181 ± 12	18 ± 1%	726	146 ± 25	20 ± 3%	1,058	263 ± 28	25 ± 3%
2010	950	183 ± 10	19 ± 1%	730	157 ± 20	21 ± 3%	1,003	264 ± 25	26 ± 3%
2011	881	143 ± 9	16 ± 1%	701	133 ± 19	19 ± 3%	886	203 ± 20	23 ± 3%
2012	897	155 ± 9	17 ± 1%	722	147 ± 21	20 ± 2%	927	250 ± 24	27 ± 3%
2013	960	157 ± 19	16 ± 2%	751	180 ± 40	24 ± 5%	997	242 ± 53	24 ± 5%

Table A 3. Gas savings by pre-Wx usage bins, by building type.

Housing Type	Usage Bin (therms)	Pre-Wx Usage (therms)	Net Savings (therms)	Net Savings (%)
Single-Family, Site-Built	<600	503	23 ±6	5 ±1%
	600-750	679	74 ±7	11 ±1%
	750-900	824	125 ±8	15 ±1%
	900-1,100	993	175 ±10	18 ±1%
	>1,100	1,394	321 ±15	23 ±1%
2-4 Unit	<600	503	47 ±14	9 ±3%
	600-750	679	103 ±24	15 ±3%
	750-900	825	192 ±24	23 ±3%
	900-1,100	997	269 ±27	27 ±3%
	>1,100	1,418	447 ±31	32 ±2%
Mobile Home	<500	441	16 ±18	3 ±5%
	500-650	578	100 ±16	17 ±3%
	650-800	702	134 ±24	19 ±4%
	800-1,000	819	187 ±24	23 ±3%
	>1,000	1,064	298 ±42	28 ±4%

Table A 4. Incidence of key measures in gas-heated single-family homes.

Description of Metric	2009	2010	2011	2012	2013
Number of treated homes (gas heated, SF)	2,633	3,949	4,919	3,300	2,134
Incidence, All Attic	83%	85%	86%	86%	77%
Incidence, Unfloored	75%	75%	78%	78%	69%
Incidence, Unfloored (No existing)	14%	17%	14%	21%	21%
Incidence, Enclosed	32%	33%	32%	33%	30%
Incidence, Wall Insulation	40%	35%	31%	28%	28%
Ave SF Added, Wall Insulation	1,086	1,022	995	997	990
Incidence, All Replacements (w/ WHEAP)	59%	57%	51%	48%	45%
Incidence, All Replacements (w/out WHEAP)	53%	51%	45%	40%	34%
Incidence, Furnace, Energy Conservation	43%	40%	34%	28%	25%
Incidence, Furnace, Health and Safety	5.5%	5.2%	6.4%	7.8%	7.0%
Incidence, Boiler, Energy Conservation	4.7%	4.9%	4.0%	3.0%	1.8%
Incidence, Boiler, Health and Safety	0.8%	0.7%	0.9%	1.1%	0.4%
Incidence, DWH, Health and Safety	29%	34%	32%	28%	21%
Incidence, DWH, Fuel Switch	8%	7%	9%	10%	14%
Incidence, Refrigerator	43%	46%	42%	39%	37%
Incidence, Freezer	15%	16%	16%	14%	12%
Ave "As-is" Blower Door Reading	3,104	2,840	2,599	2,616	2,765
Ave "Post" Blower Door Reading	2,097	1,952	1,794	1,792	1,917
Ave Reduction, "As-is" to "Post"	1,050	933	824	841	875
Mechanical Ventilation	61%	62%	69%	72%	54%

Table A 5. Electricity savings for homes in 1-4 unit buildings, by fiscal year.

	Housing Units in 1-4 Unit Buildings			
Fiscal Year	Pre-Wx Usage	kWh Savings	% Savings	Housing Units Analyzed
2009	8,984 ± 125	1,144 ± 93	13 ± 1%	3,117
2010	8,882 ± 101	1,046 ± 76	12 ± 1%	4,854
2011	8128 ± 80	839 ± 62	10 ± 1%	5,848
2012	8,642 ± 97	831 ± 74	10 ± 1%	4,339
2013	8,975 ± 548	1022 ± 247	11 ± 3%	967

Table A 6. Electricity savings, by fiscal year and housing type

Fiscal Year	Single Family, Site Built			Mobile Home			2-4 Unit		
	Pre-Wx Usage	kWh Savings	% Savings	Pre-Wx Usage	kWh Savings	% Savings	Pre-Wx Usage	kWh Savings	% Savings
2009	9,546	1,312 ± 85	14 ± 1%	8,373	1,059 ±188	13 ± 3%	7,925	853 ± 209	11 ± 2%
2010	9,396	1,111 ± 72	12 ± 1%	8,502	856 ± 177	10 ± 3%	7,775	967 ± 179	12 ± 2%
2011	8,687	906 ± 73	10 ± 1%	7,832	915 ± 193	12 ± 3%	6,867	716 ± 161	10 ± 2%
2012	9,164	950 ± 85	10 ± 1%	9,182	1028 ± 244	11± 2%	7,259	424 ± 178	6 ± 2%
2013	9,340	1,174 ± 304	13 ± 3%	9080	583 ± 751	6 ± 7%	7,823	1,037 ± 453	13 ± 7%

Table A 7. Electricity savings, by pre-weatherization usage and housing type.

Housing Type	Usage Bin (kWh)	Pre-Wx Usage (kWh)	Net Savings (kWh)	Net Savings (%)
Single-Family, Site-Built	<5,500	4,247	438 ± 54	9 ± 2%
	5,500-7,500	6,476	706 ± 77	10 ± 2%
	7,500-9,500	8,462	711 ± 104	7 ± 2%
	9,500-12,500	10,873	1,193 ± 125	10 ± 2%
	>12,500	15,598	2,147 ± 176	13 ± 2%
2-4 Unit	<4,250	3,353	239 ± 101	4 ± 6%
	4,250-5,500	4,864	236 ± 170	1 ± 6%
	5,500-7,250	6,336	667 ± 182	8 ± 5%
	7,250-9,250	8,192	864 ± 234	8 ± 5%
	>9,250	12,442	1,869 ± 358	12 ± 6%
Mobile Home	<5,000	3,996	376 ± 129	6 ± 7%
	5,000-7,000	6,034	396 ± 195	3 ± 7%
	7,000-9,000	7,933	849 ± 253	8 ± 7%
	9,000-12,000	10,403	1,036 ± 336	7 ± 7%
	>12,000	14,672	2,001 ± 517	10 ± 7%

Table A 8. Average SIRs (with 90% confidence intervals) and job costs for homes treated during FY13 including WHEAP furnace replacements.
SIRs for oil- and propane-heated homes are approximations based on electricity and therm savings estimates for gas-heated homes and a set of adjustments.

Housing Type	Heating Fuel	With Health and Safety		No Health and Safety		With Health and Safety and WHEAP	
		SIR	Ave Job Cost ($)	SIR	Ave Job Cost ($)	SIR	Ave Job Cost ($)
All 1-4 Unit	Combined	1.43 ± 0.11	$5,368	1.73 ± 0.13	$4,437	1.35 ± 0.10	$5,653
	Gas	0.96 ± 0.09	$5,061	1.18 ± 0.11	$4,111	0.91 ± 0.09	$5,358
	LPG	1.92 ± 0.17	$5,630	2.29 ± 0.20	$4,716	1.85 ± 0.16	$5,853
	Oil	2.94 ± 0.14	$6,938	3.34 ± 0.16	$6,108	2.81 ± 0.13	$7,268
Single-Family, Site-Built	Combined	1.37 ± 0.13	$5,713	1.66 ± 0.16	$4,704	1.30 ± 0.12	$6,040
	Gas	0.90 ± 0.11	$5,439	1.11 ± 0.13	$4,396	0.84 ± 0.10	$5,802
	LPG	1.68 ± 0.19	$5,798	2.03 ± 0.22	$4,795	1.62 ± 0.18	$5,986
	Oil	2.89 ± 0.17	$7,015	3.28 ± 0.19	$6,179	2.75 ± 0.16	$7,367
Mobile Home	Combined	1.29 ± 0.32	$4,982	1.49 ± 0.37	$4,304	1.16 ± 0.29	$5,530
	Gas	0.67 ± 0.25	$4,768	0.78 ± 0.29	$4,108	0.58 ± 0.22	$5,509
	LPG	1.97 ± 0.48	$5,164	2.27 ± 0.55	$4,476	1.85 ± 0.45	$5,487
	Oil	1.87 ± 0.45	$7,052	2.17 ± 0.53	$6,081	1.82 ± 0.44	$7,233
2-4 Unit	Combined	1.59 ± 0.33	$4,467	1.96 ± 0.40	$3,622	1.57 ± 0.32	$4,514
	Gas	1.44 ± 0.32	$4,402	1.79 ± 0.39	$3,553	1.43 ± 0.31	$4,450
	LPG	2.57 ± 0.51	$6,225	2.96 ± 0.58	$5,410	2.57 ± 0.51	$6,225
	Oil	4.70 ± 0.49	$5,881	5.35 ± 0.55	$5,163	4.64 ± 0.48	$5,952

Appendix B – Measure Analysis

Methodology

Statistical regression analysis was used to estimate the average savings associated with individually installed measures. In this approach, annual gas or electric savings for individual households were regressed against installation indicators for various measures.

The analysis provides a set of coefficients that best explain the house-to-house variation in savings as a function of the presence or absence of various measures. The best-fit regression coefficients can then be taken as estimates of the average savings associated with installation of the measure. For example, if the square footage of wall insulation installed is included as a predictor variable, then the regression coefficient for this variable indicates the average gas savings associated with each square foot of added wall insulation.

While a large number of measures are installed by the program, some are not amenable to this type of analysis because they either have too small of an impact on gas or electricity consumption, or are installed too infrequently to be statistically discerned from the available data. Moreover, a wide variety of model specifications are possible and different specifications can lead to very different savings estimate for the same measure. Finally, measures are sometimes typically installed together or are associated with particular household characteristics that can make it difficult for this type of analysis to tease out individual savings effects.

To guard against misleading results, the analysis was implemented only for households with reasonably reliable consumption data, and was restricted to cases where annual savings were estimated to lie with the range of -75 to +75 percent of pre-weatherization consumption. Cases with outlier and questionable values of predictor variables were removed from the analysis. For example, cases with added wall insulation of unity (1) or more than 2,500 ft^2 were removed, as were cases where pre- or post-weatherization measure air leakage was listed as an even multiple of 100 CFM_{50} (likely indicating an estimate rather than a measure value). The data were also analyzed for evidence of problematic co-linearity and influential data points. Finally, though not shown here, the models were run for various subsets of the data (e.g. by FY, omitting jobs with heating system replacement, etc.) and under alternative robust and mixed-effects specifications to assess the sensitivity of the results.